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Review of Considerations, Management, and Treatment of Medical Emergencies During Commercial Flight

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14. ABSTRACT
As the overall health of our world's population improves, life expectancy will increase, leading to an older population using air transport. With this aged population comes a variety of chronic medical conditions that may become exacerbated during commercial flight, increasing the probability of in-flight medical emergencies. Thus, primary care providers need a better understanding of the aviation environment to make reasonable decisions concerning medical clearance for flying. In this report, the medical resources onboard most civilian commercial airlines, the contents of the medical kits, and the training background of the crew in response to in-flight medical events are reviewed. Ground-based medical support agencies are introduced, and the physiology of the respiratory system is outlined. General guidance for responding to medical events onboard, with decision strategy for determining aircraft diversion, is provided, along with a discussion of the top four most common in-flight medical events. Finally, a brief history of international standards is given to compare the procedures between the United States and the international communities. The medical community as a whole may benefit from a greater understanding of the aviation environment and how this can adversely impact a patient's chronic illness state. Also, since many healthcare providers are at some point passengers onboard commercial aircraft, a greater understanding of managing in-flight emergencies, capabilities, logistics, and resources would also be beneficial for appropriate response procedures. In addition, standardization of the medical kits between the Federal Aviation Administration and International Civil Aviation Organization and maximum availability of automated external defibrillators during flight would likely improve the overall potential for successful assistance during an in-flight medical emergency.

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1.0 SUMMARY

As the overall health of our world's population improves, life expectancy will increase, leading to an older population using air transport. With this aged population comes a variety of chronic medical conditions that may become exacerbated during commercial flight, increasing the probability of in-flight medical emergencies. Thus, primary care providers need a better understanding of the aviation environment to make reasonable decisions concerning medical clearance for flying. In this report, the medical resources onboard most civilian commercial airlines, the contents of the medical kits, and the training background of the crew in response to in-flight medical events are reviewed. Ground-based medical support agencies are introduced, and the physiology of the respiratory system is outlined. General guidance for responding to medical events onboard, with decision strategy for determining aircraft diversion, is provided, along with a discussion of the top four most common in-flight medical events. Finally, a brief history of international standards is given to compare the procedures between the United States and the international communities. The medical community as a whole may benefit from a greater understanding of the aviation environment and how this can adversely impact a patient's chronic illness state. Also, since many healthcare providers are at some point passengers onboard commercial aircraft, a greater understanding of managing in-flight emergencies, capabilities, logistics, and resources would also be beneficial for appropriate response procedures. In addition, standardization of the medical kits between the Federal Aviation Administration and International Civil Aviation Organization and maximum availability of automated external defibrillators during flight would likely improve the overall potential for successful assistance during an in-flight medical emergency.

2.0 INTRODUCTION

Managing in-flight medical events on a commercial airliner can be a frightening and stressful task, given the limitations of trying to provide medical care in the confined space of the passenger compartment with the noise and vibration encountered during flight. The additional element of the unknown medical condition and medical history of the passengers creates uncertainty in determining the true severity of the episode, the available treatment on the aircraft, and whether or not the episode warrants immediate diversion [1]. In a study looking at all commercial flights worldwide from 2008 through 2010, it was found that there was one in-flight medical emergency per 604 flights, totaling 11,920 medical emergencies that required a call to the medical ground support center [1]. The most common medical emergency was determined to be syncope or presyncope at 37.4%, respiratory issues at 12.1%, and gastrointestinal issues such as nausea or vomiting at 9.5% [1].

When a medical event occurs during commercial passenger flight, as a responding healthcare provider, what will you do? Do you know what resources are available on the aircraft, and is there a communication link available for ground support? How can the aircrew assist you? What is your legal liability? These are several of the many questions that should be considered when responding to the call for help. This report provides answers to those questions and background on the most common medical emergencies in flight, treatment and management capabilities, and diversion guidance using established guidelines from the Federal Aviation Administration (FAA).

3.0 ONBOARD FIRST AID KITS AND AUTOMATED EXTERNAL DEFIBRILLATORS

Commercial aircraft fall under the jurisdiction of the country from which the aircraft operates and must follow the legal requirements for that country in terms of medical supplies and equipment carried [2]. The responsible aviation authority for the United States is the FAA, whereas Europe falls under the European Aviation Safety Agency and the Joint Aviation Authorities, and both agencies comply with the International Civil Aviation Organization (ICAO) [2,3]. For the United States, FAA standards, specifically Title 14 of the Code of Federal Regulations, Part 121, Appendix A, specifies the difference between first aid kits and emergency medical kits [4]. First aid kits are small medical aid kits that contain basic first aid provisions, such as bandages, splints, scissors, and tape (see Table 1) [4]. The number of first aid kits required depends on the number of passengers that the aircraft is capable of carrying. For example, for 0-50 passengers, at least one first aid kit must be onboard the aircraft (see Table 2) [4]. An emergency medical kit, which must be on all passenger flights requiring a flight attendant, contains a variety of medications, intravenous (IV) access supplies, and basic airway management supplies (see Table 3) [4]. Additionally, at least one automated external defibrillator (AED) must be readily available in the passenger cabin on all transport flights that require a flight attendant and have a maximum payload capacity of more than 7500 pounds [4,5]. The AEDs must meet U.S. Food and Drug Administration requirements for legal marketing within the United States [4], must comply with FAA Technical Standard Order requirements concerning power sources for aviation-based electronic devices, and must be maintained as specified by the manufacturer [4].

It is interesting to note that for the United States, FAA regulations mandate medications for the treatment of acute coronary syndrome and advanced cardiac life support, along with the requirement to carry the AED. However, medications such as anti-emetics are not mandatory items for the emergency medical kits, which could easily be a justifiable addition to this kit.

Table 1. First Aid Kit Contents [4]

Contents	Quantity
Adhesive bandage compresses, 1 in	16
Antiseptic swabs	20
Ammonia inhalants	10
Bandage compresses, 4 in	8
Triangular bandage compresses, 40 in	5
Arm splint, non-inflatable	1
Leg splint, non-inflatable	1
Roller bandage, 4 in	4
Adhesive tape, 1 in standard roll	2
Bandage scissors	1

Table 2. Minimum Number of First Aid Kits Required [4]

No. of Passenger Seats	No. of First Aid Kits
0-50	1
51-150	2
151-250	3
More than 250	4

Table 3. Emergency Medical Kit Contents [4]

Contents	Quantity
Sphygmomanometer	1
Stethoscope	1
Airways, oropharyngeal (3 sizes) 1 pediatric, 1 small adult, 1 large adult or equivalent	3
Self-inflating manual resuscitation device with 3 masks (1 pediatric, 1 small adult, 1 large adult or equivalent)	1:3 masks
CPR mask (3 sizes), 1 pediatric, 1 small adult, 1 large adult or equivalent	3
IV administration set: tubing with 2 Y connectors	1
Alcohol sponges	2
Adhesive tape, 1 in, standard roll adhesive	1
Tape scissors	1
Tourniquet for IV start	1
Saline solution, 500 cc	1
Protective nonpermeable gloves or equivalent, pairs	1
Needles (2-18 ga; 2-20 ga; 2-22 ga)	6
Syringes (1-5 cc, 2-10 cc, or sizes necessary)	4
Analgesic, non-narcotic, tablets, 325 mg	4
Antihistamine tablets, 25 mg	4
Antihistamine injectable, 50 mg (single dose ampule or equivalent)	2
Atropine, 0.5 mg, 5 cc (single dose ampule or equivalent)	2
Aspirin tablets, 325 mg	4
Bronchodilator, inhaled (metered dose inhaler or equivalent)	1
Dextrose, 50%/50 cc injectable (single dose ampule or equivalent)	1
Epinephrine 1:1000, 1 cc injectable (single dose ampule or equivalent)	2
Epinephrine 1:10,000, 2 cc injectable (single dose ampule or equivalent)	2
Lidocaine, 5 cc, 20 mg/mL injectable (single dose ampule or equivalent)	2
Nitroglycerin tablets, 0.4 mg	10
Basic instructions for use of the drugs in the kit	1

CPR = cardiopulmonary resuscitation.

4.0 CREW MEMBER TRAINING AND CAPABILITIES

One of the most vital resources onboard an aircraft during a medical emergency is the crew. Crew members can facilitate communication with the pilot in command, help with decisions of whether to continue to destination or divert, and aid with any evaluation and treatment of the sick passenger. According to Advisory Circular 121-34B, all aircraft crew members must receive initial and periodic training for basic emergency medical events [6]. Emphasis on procedures for managing emergencies, as well as crew coordination, is a requirement for this training. All crew members should be familiar with the emergency medical equipment, such as proper function, usage, and location, to ensure that the required equipment and supplies can be rapidly located during an emergency. Interestingly, as a safety feature, the emergency medical kit and AED are specifically required items indicated on the Minimum Equipment List for that particular aircraft and are, therefore, requirements that must be

replenished or replaced after each use before that aircraft can depart [6]. Accordingly, the crew must be trained in the replacement and replenishment process [6].

Flight attendants additionally must be instructed in initial and recurrent training for proper use of the AED and must demonstrate skills in performance drills [6]. CPR is also considered part of the initial training platform for flight attendants, and they must have recurrent training in CPR and basic life support (BLS), including AED use, every 24 months [6]. This training requirement ensures that flight attendants can expediently locate the medical supplies and AED and quickly and properly use the equipment to optimize the best outcome for the sick passenger.

It is important to note that there is no set standard curriculum that air carriers must utilize for training crew members. It is expected that they conform to the American Red Cross and American Heart Association standards, but they do not have to use these programs to meet FAA training requirements [6]. Also, there is no specified number of training hours mandated for either the CPR or BLS/AED classes [6]. The goal of the recurrent training is to establish a familiarity with the emergency medical equipment and a general knowledge of location and function, rather than training the flight crew to be medical treatment personnel.

5.0 GROUND SUPPORT FOR MEDICAL CONSULTATION

When a medical event occurs on a commercial airline, medical consultation is often available via satellite telephone to ground support. There are several companies that specialize in providing this type of service, such as MedAire, from Banner Good Samaritan Hospital, Phoenix, AZ; Stat-MD, from the University of Pittsburgh Hospital, Pittsburgh, PA; and The First Call, from England [7-10]. These ground-based medical consultation services establish a 24-hour, 7-day, 365-days-per-year response capability for real-time medical advice [5,8-10]. These companies create a global response service for airlines, ships, and other types of industries and market their capabilities for airport fit-to-fly assessments, emergency medical kit logistics, and crew member training programs [8]. According to Dr. Paulo Alves, Global Medical Director, Aviation Health, from MedAire Inc., the most common reported medical events consist of gastrointestinal symptoms, followed by vasovagal syncope (Alves P. Personal communication; 2017 Feb 23). This is likely due to the longer duration of international flights (Alves P. Personal communication; 2017 Feb 23). The consultation services at these ground-based centers are provided by emergency medicine physicians and are held to the comparable level of standard of care as ground-based emergency services [8] (Alves P. Personal communication; 2017 Feb 23).

6.0 REVIEW OF MOST COMMON MEDICAL EMERGENCIES IN FLIGHT: THE FLIGHT ENVIRONMENT

Air travel has become quite the luxurious mode of transportation in the past few decades, but several factors can impact baseline medical conditions and quality of health. For example, the relative hypoxic environment that results from cabin pressurization can actually alter a passenger's ability to compensate fully and may be detrimental to those with significant morbidity [9,11].

To understand this potential for decompensation among travelers with chronic disease, let's review respiratory physiology. Davis et al. describe the five components of the oxygen delivery system in humans as ventilation, pulmonary diffusion, transportation, tissue diffusion, and cellular utilization [12].

Ventilation is the first component to consider in respiratory physiology, where gas exchange with the atmosphere occurs in the pulmonary alveoli. This is reliant upon a patent airway tract and intact mucociliary clearance system to remove particulate matter from the inspired ambient air. Ventilation is also dependent upon normal lung volumes and elasticity of healthy tissue to bring inhaled ambient air to the site of gas exchange [12]. Another key factor in ventilation is presence of an intact and functioning pulmonary vascular bed to present blood flow for gas exchange to occur [12]. This allows for appropriate volume redistribution, or shunting, of blood flow to the open alveoli, which is influenced by gravity, inertial force of G, and environmental oxygen availability [11,12].

The actual exchange of gases occurs during pulmonary diffusion, during which oxygen and carbon dioxide (CO_2) move between the alveoli and pulmonary vasculature [12]. The pulmonary vasculature is vast, creating an enormous surface area for passive diffusion of respiratory gases to occur [12]. However, increased alveolar membrane thickness, as is seen in interstitial lung disease, may interfere with the diffusion of gases in a hypoxic environment [12].

Once the gases have been exchanged between the pulmonary vasculature and alveolus, blood flow of erythrocytes serves to transport gases throughout the vascular system [12]. Fundamental to understanding this process is the concept of the oxyhemoglobin dissociation curve. Hemoglobin, which is considered a carrier protein, has the capability to upload and offload oxygen depending on its partial pressure in the particular tissue [12]. The hemoglobin protein itself is a tetramer of polypeptide chains, each complexed with a protoporphyrin ring and ferrous iron molecule, which are collectively called the heme moiety [12]. Each heme moiety can bind to an oxygen molecule, and this becomes sequentially easier as oxygen is attached. Given that there are four positions for oxygen binding on hemoglobin, a resulting sigmoidal-shaped curve is produced when plotting oxygen saturation percentage and the partial pressure of oxygen [12]. The flattened portion of the curve physiologically is beneficial, in that larger decrements in the partial pressure of oxygen, such that occur during flight or high-altitude dwelling, are not detrimental to arterial oxygen saturation. Oxygen is loaded onto the hemoglobin transport protein at the alveoli, with each successive molecule of oxygen loading easier than the last [12]. This phenomenon holds true until about 60 mmHg oxygen pressure, where the oxyhemoglobin dissociation curve forms a steep decline, and even small partial pressure changes significantly impact the arterial oxygen saturation, thus liberating oxygen from the hemoglobin protein carrier for diffusion to the tissues [12,13]. The oxyhemoglobin dissociation curve is affected by many conditions, most notably pH, known as the Bohr effect [12]. As the hydrogen ion concentration is increased, indicated by a decrease in pH, the oxyhemoglobin dissociation curve is shifted to the right, where it is easier for hemoglobin to release oxygen to the tissues [12]. If, however, the pH increases, a subsequent decrease in hydrogen ions, the curve shifts leftward, favoring the uptake of oxygen molecules by pulmonary diffusion [12]. Increases in body temperature, increased partial pressure of CO_2, or increased levels of 2,3-diphosphoglycerate will facilitate a right shift of the dissociation curve, thus favoring oxygen release to tissues [12]. Conversely, a reduction in these parameters causes a leftward shift, favoring oxygen uptake onto the hemoglobin molecule.

Carbon dioxide also plays a significant part in oxygen uptake and offloading. Given its increased solubility in tissue fluids compared with oxygen, CO_2 undergoes formation to bicarbonate within the erythrocytes, reducing the partial pressure of CO_2 in the tissues, thus favoring its uptake for elimination [12]. At the systemic capillary level, the offloading of oxygen enhances the formation of bicarbonate within the erythrocyte, which leads to increased CO_2 binding, termed the Haldane effect [12]. Additionally, some CO_2 combines with proteins to form carbamino compounds, which are increased after oxygen has been offloaded, furthering the uptake of CO_2 for elimination from the tissues [12].

Factors outside of the cellular level of respiratory physiology that impact oxygen and CO_2 transport include anemia and cardiac output [12]. In the case of anemia, a reduction in the amount of hemoglobin present for binding to oxygen will reduce the overall oxygen-carrying capacity of the blood, shifting the dissociation curve to the left, favoring oxygen uptake [12]. In a healthy adult, cardiac output can increase to facilitate greater oxygen transport, although coronary blood flow will concomitantly increase to meet the heart's oxygen demand as well. However, in cardiac disease, reduced cardiac output will result in a decrease in the oxygen transport capability of the blood [9,12].

Tissue diffusion of oxygen from the hemoglobin in the erythrocytes within the vasculature to mitochondria in the tissue cells is dependent upon several factors, such as the tissue area, thickness of the tissue membranes, the partial pressure difference of the gas, and the solubility of the gas in the tissues [12]. Also, terminal arterioles have the capability of recruiting more arterioles to alter their level of resistance of blood flow through the tissue [12]. Increased hydrogen ions, increased CO_2 tension in a tissue, and lowered oxygen tension may stimulate terminal arterioles to recruit more capillaries to improve blood flow to this particular area of tissue, facilitating gas exchange [12]. Finally, once the tissues have received oxygen, cellular utilization via oxidative phosphorylation by the mitochondrial cytochrome system, and to a much lesser degree glycolysis and the Kreb's cycle, occurs to produce adenosine triphosphate for cellular energy [12].

Why is an understanding of this respiratory physiology relevant to the commercial air transport environment? Lung disease, heart disease, and anemia are a few conditions that directly impact the oxyhemoglobin dissociation curve, which must be considered when clearing a patient to fly as a passenger aboard a commercial airliner. A basic understanding of the key components will enable healthcare workers to assess their patient's condition for medical clearance to fly in the relatively hypoxic environment that occurs at altitude. Furthermore, this physiological understanding will aid the volunteer passenger physician in providing assistance to a sick passenger [2]. The Aerospace Medical Association website provides additional guidance material for health professionals [14].

7.0 GENERAL GUIDANCE FOR PROVIDING IN-FLIGHT MEDICAL CARE AND DIVERSION

Peterson et al. conducted a study of five domestic and international airlines that contracted with ground-based medical assistance from January 2008 through October 2010 [1]. Of the 11,920 in-flight medical emergencies that requested ground-based medical assistance (1 medical emergency for every 604 flights), the most common medical problems were syncope/presyncope (37.4%), respiratory symptoms (12.1%), and nausea/vomiting (9.5%) [1]. These medical emergencies resulted in physician passenger assistance 48.1% of the time, and

7.3% of these emergencies resulted in aircraft diversion [1]. Upon hospital follow-up for those patients available, Peterson et al. found that reasons for admission were mostly due to stroke, respiratory, and cardiac symptoms [1]. This study highlights the key point that it is often difficult to categorize symptoms while in flight. Symptoms may present onboard very subtly, but may in actuality be indicative of a more insidious process [1]. This should alert the responding medical personnel or flight crew to have a higher index of suspicion when managing a potentially concerning medical issue.

Attempting to evaluate and possibly treat a sick passenger onboard a commercial passenger aircraft poses many difficulties. The noise from the engines during flight, the cramped space in the passenger seats and aisle, and lack of any past medical information about the passenger are only a few impediments that make providing medical care extremely difficult in flight [9,15]. The focus, therefore, should be on stabilizing the passenger with whatever condition is evolving rather than trying to make an absolute diagnosis in this uncertain setting with logistical limitations [9].

When a sick passenger is discovered, whether by the flight crew or by another passenger, enlist the help of the flight attendants, as they are trained for such scenarios and know the basic processes for responding to this sort of situation. Locate the first aid kit, emergency medical kit, supplemental oxygen (if carried), and AED, depending on the presentation of the sick traveler [9]. Perform a quick assessment of the passenger's condition, vital signs, and pain in the passenger's seat; then, if necessary and feasible, move the passenger to the aisle or galley area for further evaluation or comfort, keeping in mind safety constraints for exiting the aircraft [1]. Since blood glucose monitors are not required items in emergency medical kits, and hypoglycemia can cause altered mental status, Nable et al. recommend ascertaining if the aircraft has a blood glucose meter or if any other passengers have a meter available to use for the passenger in distress [5,16]. The flight attendants have direct communication to the pilot in command, who bears the ultimate responsibility for ensuring the safety of the passengers being transported and therefore makes the decision concerning medical treatment for the ill passenger [5].

Aircraft diversion is a costly decision, estimated between $15,000 and $900,000 [5,9]. Therefore, this decision warrants collaboration with the ground-based medical team representing the airline, the treating medical personnel onboard the flight, and the pilot in command [1,5]. Contact ground-based medical support if this is an available service. Based on their recommendations and those providing care for the sick passenger, along with the pilot in command, a decision concerning diversion versus continuation with the flight should be made [5,9]. There are several logistic concerns that also play a role in the decision to continue with the flight plan or divert, such as fuel load, weather conditions, airport services, proximity to ground medical care and capabilities, and air traffic control [5]. These factors must be anticipated in this multifactorial equation when dealing with a potentially life-threatening medical event onboard a commercial airliner [1,16]. Chandra and Conry found unremitting chest pain, shortness of breath, severe abdominal pain, stroke, persistent unresponsiveness, refractory seizures, and severe agitation as the most common medical reasons for aircraft diversion [5]. This emphasizes the significance of a preflight physical to assess if a patient is fit to fly, thus preventing a life-threatening medical emergency at 38,000 feet onboard a commercial airliner [2].

8.0 REVIEW OF MEDICAL EVENTS THAT MAY OCCUR IN FLIGHT

8.1 Syncope/Presyncope

Syncope is described as a loss, or near loss, of postural tone and transient loss of consciousness [17,18]. This is a quite common medical condition, affecting most people at some point in their lives and responsible for up to 5% of all emergency department visits [18]. Even after hospital admission, Probst et al. found that one-third of syncope hospital admissions had no other etiology found at discharge to explain the loss of consciousness [17]. Unfortunately, however, as many as 11% of syncopal cases reported within the United States were accompanied with serious etiologies, such as myocardial infarction, cardiac dysrhythmia, cerebral vascular accidents, and even death [18]. As such, syncope or presyncope remains the most common medical emergency encountered in commercial flight, accounting for over 37% of reported in-flight medical emergencies [1,16]. Although the term “syncope” or “presyncope” can represent a wide variety of medical conditions, this alteration in consciousness is the most commonly encountered medical illness during commercial flight for several reasons [18].

First, as previously discussed, most commercial passenger airplanes fly at altitudes of 24,000 to 40,000 feet, which makes the cabin environment slightly hypoxic, even though the cabins on most of these aircraft are usually pressurized to 6000-8000 feet [9,11]. This causes a physiologic drop in arterial oxygen partial pressure to 60 mmHg from a normal value of 75 to 100 mmHg at sea level [16]. In a healthy passenger, this lowered arterial oxygen partial pressure is easily compensated for the typical short duration of U.S. domestic commercial flights. However, in those with underlying medical illnesses, such as cardiac or respiratory problems, this lowered arterial oxygen partial pressure, resulting in diminished tissue oxygen utilization as previously described, may exacerbate the medical condition, leading to a spectrum of altered consciousness [9,12]. Smoking further insults this delicate physiology, in that chronic smokers already have a decreased oxygen-carrying capacity due to persistent carboxyhemoglobin levels, diminished respiratory capacity, and developing cardiovascular disease [9].

Second, dehydration can lead to a worsened clinical picture in the setting of this cabin-induced hypoxia, in that the total blood volume may become contracted, leaving less blood volume for circulation [16]. Orthostatic hypotension can occur during the setting of dehydration, allowing blood pooling in the lower extremities, resulting in less venous return to the heart and subsequently a reduction in cardiac output, causing a transient diminished blood flow to the brain and, ultimately, prostration [19]. Passengers onboard commercial flights may become dehydrated due to several reasons. The airport and aircraft environments contribute to an arid setting, and the passengers’ increased physical activity in locating connecting flights adds an exertional component, compounded by a lack of normal eating and drinking schedules [16]. The airplane environment during flight becomes extremely dry as the pressurization process occurs. Air that has passed around the engine compartment to become pressurized for the cabin loses its humidity, resulting in a relatively arid cabin environment with a relative humidity of less than 10% [2,9,12,16]. Added to this dehydration, fatigue due to stress, altered sleep schedule, noise, and vibration of the aircraft may also contribute to lessened capacity for compensation in the setting of chronic medical disease, thus potentiating altered consciousness [18].

Upon notification of a passenger who has altered mental status, advise a flight attendant to locate the medical kits and the AED [9]. Attempt to evaluate the passenger for responsiveness, breathing, pulse, and vital signs, although this may be extremely difficult given the constraints of

passenger compartments on many airlines [2]. If necessary, place oxygen on the patient, start IV fluids from the medical kit, and attach the AED. If you suspect that the passenger is hypoglycemic, try to borrow a glucose meter from another passenger, and a limited amount of dextrose is available in the medical kit [4,16]. If arousable and able to communicate, administer oral fluids if the patient is dehydrated and orthostatic [9]. Otherwise, good CPR in the event that the passenger is not breathing and does not have a pulse, attachment of the AED, and consultation with the ground support agency with the pilot's decision to divert the aircraft or continue with the flight are the capabilities for managing syncope of unknown origin [16].

8.2 Respiratory Issues

As previously mentioned, the Peterson et al. study found that 12.1% of all medical emergencies during commercial passenger flight were related to respiratory issues [1]. Very common are acute exacerbations of chronic obstructive pulmonary disease and pulmonary hypertension, which may lead to hypoxic symptoms during flight at higher altitudes [16]. Chronic obstructive pulmonary disease (COPD) is a leading cause of morbidity and mortality worldwide, resulting from chronic smoking, air pollution, asthma, and occupational exposures [20]. In fact, some estimate that COPD may eventually become the third leading cause of death by the year 2020 as the world population ages [12,20,21]. Accordingly, acute exacerbations of COPD in an older population tend to have poorer clinical outcomes [21]. The disease is characterized by an overlap of chronic bronchitis and emphysema. Chronic bronchitis induces inflammation of the airways, producing thick mucosal secretions, leading to productive cough. Emphysema actually destroys the lung parenchyma, eradicating the elasticity of the distal airspaces, leading to large blebs and bullae lacking recoil ability [12]. Consequently, this leads to a baseline mismatch in ventilation and perfusion and, thus, hypoxia [16,20]. Aeromedically, the lowered oxygen tension in the cabin altitude will only magnify the chronic hypoxia in these passengers with COPD, contributing to a myriad of respiratory issues while in flight [5,16].

Asthma is another respiratory disease that can have catastrophic outcomes if not properly managed prior to flying as a commercial airline passenger. This disease process is characterized by airway hyper-responsiveness, triggered by a vast array of stimuli, producing cough, chest tightness, wheezing, and dyspnea [12]. During a severe asthmatic attack, ventilation and perfusion are mismatched due to inflammatory constriction of airways [12]. Again, cabin altitude hypoxia will only worsen the passenger's condition when flying on a passenger air transport aircraft. Fortunately, a bronchodilator and antihistamine are available in the emergency medical kit in the event the passenger does not have his/her prescribed medication available [4].

Interstitial lung diseases represent a smaller proportion of those with acute or chronic lung diseases that may exacerbate hypoxemia during commercial flight [12]. The functional impairment of these restrictive lung diseases potentiates dyspnea, ventilation and perfusion mismatching, and ultimately hypoxia [12]. Pulmonary sarcoidosis is one of the most common interstitial lung diseases, characterized by systemic granulomatous disease affecting the eyes, brain, and heart in addition to the lungs [12].

Regardless of the etiology of the lung pathology of the passenger, providing reassurance and supplemental oxygen, administering the passenger's medications if appropriate, and consulting with the ground-based medical support will facilitate the decision of whether this passenger needs an emergency landing or can continue with the planned travel [16]. However, if the passenger rapidly deteriorates, basic airway equipment is contained in the emergency

medical kit, the pilot can descend to a lower altitude to reduce the cabin altitude, and an emergency landing can be arranged upon the pilot's declaration of an in-flight medical emergency [16].

8.3 Gastrointestinal Issues, Nausea/Vomiting/Diarrhea

Boyle's law describes the inverse relationship of the volume of gas with its pressure—hence, the observation that gas expands at altitude [9,12]. This may present significant gastric distention as the aircraft ascends, leading to abdominal discomfort, vomiting, and diarrhea [9]. Perhaps many episodes of abdominal pain, nausea, vomiting, or diarrhea aboard commercial aircraft may be due to prior illness or alcohol intoxication before the flight that become exacerbated by the gas expansion at altitude. However, a more ominous surgical process could be present, necessitating a thorough check of the passenger with these symptoms. The more significant differential diagnoses of abdominal pain with or without vomiting may include acute appendicitis, bowel obstruction, ectopic pregnancy, myocardial infarction, acute cholecystitis, acute pancreatitis, volvulus, peptic ulcer disease with or without perforation, diverticular disease, and acute abdominal aneurysm [22]. These conditions exhibit a spectrum of severity from mild to life threatening, potentially requiring emergent surgery. Therefore, if a passenger complains of these symptoms, check vital signs and triage for severity that would require consideration of an unscheduled landing [9]. As with other medical conditions, as best as possible create a comfortable setting for the passenger with nausea, vomiting, diarrhea, or abdominal pain, keeping the safety constraints in mind for emergent egress of the aircraft. An IV access kit is available in the emergency medical kit, with a small amount of saline solution if the passenger has low blood pressure, concerning for a surgical process [4]. Unfortunately, no anti-emetic is required for the emergency medical kit [4]. Also, if vomiting is present or a surgical process is suspected that will require further evaluation once medical care is available upon landing, withhold food and fluids from the passenger. Again, consult with ground medical support in conjunction with the pilot in command to help determine if the passenger requires diversion for emergent medical care [9,16].

8.4 Cardiac Issues

According to the Centers for Disease Control and Prevention, every year in the United States about 610,000 people die of heart disease, which represents one in every four deaths [23]. Additionally, over 11% of the U.S. population is currently diagnosed with heart disease, which represents an enormous contribution to healthcare expenditures [23,24]. Consequently, it is very likely that many passengers flying commercially have heart disease, and a significant proportion of these may be unstable or undiagnosed at the time of their flight. Given this alarming prevalence of heart disease in the United States, chest pain from acute coronary syndrome, dysrhythmias, manifestations of congestive heart failure, and cardiac arrest represent the spectrum of possible cardiac issues that should be anticipated onboard a commercial aircraft [16,25]. Despite the growing prevalence of heart disease in this country, Peterson et al. found that cardiac symptoms ranked fourth among all in-flight emergencies, accounting for 7.7% of medical events [1].

From a physiological standpoint, the decreased cabin pressure resulting from altitude can significantly impact the oxygen saturation of those with heart disease, as previously discussed. In coronary artery disease, atherosclerotic plaque narrows the diameter of coronary vessels, decreasing the blood flow to the myocardium, which decreases oxygenation in the tissues at baseline for those afflicted with cardiac disease [24]. The added stressors of exertion when walking to the departure gate at the airport terminal, dehydration from the flight environment, mild hypoxia from the cabin altitude, possible disrupted sleep cycle and nutrition schedule, and fatigue induced by noise and vibration have significant negative implications for a passenger with chronic heart disease [2].

Upon noticing a passenger with chest pain or with symptoms of cardiac dysrhythmia, such as appearing pale or diaphoretic or complaining of dizziness or palpitations, quickly evaluate the passenger, obtain vital signs, and administer oxygen [16,25]. If there is an optimal location to place the passenger, such as in the galley or an unoccupied aisle seat, it would be better to move the patient earlier than later in the event of circulatory collapse, requiring CPR. Locate the AED and emergency medical kit near the passenger in the event of rapid deterioration [16,25]. In addition to supplemental oxygen, an IV access kit is available with a small amount of saline, which will also establish medication access [4]. Aspirin is available for the passenger complaining of chest pain, as long as there are not absolute contraindications for its use. Nitroglycerin tablets are also available, although use with caution if no IV access is yet established. Other cardiac medications available are epinephrine, lidocaine, and atropine, with basic instructions provided in the kit, for use by a provider trained in advanced cardiac life support [4]. For cardiac arrest, administer CPR as trained and follow the guidance provided by the AED [16,25].

When possible, contact ground medical support if available and discuss with the pilot in command of the aircraft to determine the best course of action for the passenger in terms of aircraft diversion or continuance with flight as planned [1]. Peterson et al. found that in 42.1% of the cases of cardiac arrest, the flight was not diverted, as it was more expedient to continue to destination or diversion was not logistically feasible [1].

9.0 DEATH WHILE IN FLIGHT

While the death rate among all reported in-flight medical emergencies is extremely small, at 0.3%, this is a phenomenal source of anxiety for all the crew and fellow passengers onboard a commercial aircraft [1]. Cummins et al. found that the average death rate was 0.31 per million passengers, and these deaths were mostly related to cardiac issues [26]. For the FAA, there are no specific rules governing deaths of passengers during commercial flights [4]. If the in-flight medical event culminates in the death of the passenger, place the body in the least intrusive area so as to not prohibit other passengers from egressing the aircraft and to allow the flight crew to perform their duties; if available, notify ground-based medical support [9]. If you assist with treatment, maintain a written record of events to provide to the airline and, to respect the privacy of the passenger's care, refrain from discussing the events with the media [16].

10.0 VOLUNTEER PROVIDER LEGAL RAMIFICATIONS

Many countries mandate that a physician must render care in the event of an emergency, even if the emergency is during a commercial flight [2,16]. However, the United States is not subject to such regulation; hence, many passenger physicians are hesitant to provide in-flight medical care to an ailing passenger [14-16]. Additionally, the country under which the airline operates maintains jurisdiction and enforcement in the event of a medical emergency [2,16]. Subsequently, the Aviation Medical Assistance Act of 1998 was enacted in the United States to help delineate domestic medical care capabilities while in flight [16,27]. It specifically provides volunteer medical provider protection through the "Good Samaritan" provision, which states:

> *An individual shall not be liable for damages in any action brought in a Federal or State court arising out of the acts or omissions of the individual in providing or attempting to provide assistance in the case of an in-flight medical emergency unless the individual, while rendering such assistance, is guilty of gross negligence or willful misconduct* [27].

Interestingly, according to Title 14 of the Code of Federal Regulations, Part 121 Final Rule, the FAA does not require certificate holders or their agents to provide any medical care to passengers [28]. However, as defined in Part 121, flight crew members will comply with basic medical training, and first aid kits, emergency medical kits, and AEDs will be onboard as required [4]. Furthermore, many airlines, both in the United States and internationally, contract with a ground medical support center to provide medical guidance in the event of a medical event [1]. Even with these safeguards in place, there may still be concern of liability in volunteering to render medical aid during an in-flight emergency [1]. Fortunately, the "Good Samaritan" provision protects medically qualified nonemployee passengers who legitimately provide care to an ailing passenger [28]. According to this provision, as long as the provider of in-flight medical care is medically qualified, acting in good faith, without gross negligence or willful misconduct, this provider will be covered under the Aviation Medical Assistance Act of 1998 [15,27]. Therefore, it is recommended that volunteer physicians offering medical care onboard a commercial flight perform duties within their scope of care and should certainly refrain from providing care if under the influence of alcohol or other substances [16]. As of this writing, there are no documented cases of lawsuits brought upon a volunteer healthcare provider for rendering medical aid to an ailing passenger while in flight [5,14,15].

11.0 INTERNATIONAL REQUIREMENTS

In 1909, the first recorded powered flight across the English Channel was completed by Louis Bleriot [12]. This remarkable event signified a growing increase in aviation in Europe, and accordingly, the French Government recognized the overwhelming need for standardization of air navigation among the neighboring countries [12]. However, this attempt at international standardization was temporarily thwarted by World War I in 1914. This First World War saw the expansion of aviation throughout Europe, further necessitating aviation and navigation agreements [12]. At the conclusion of World War I, the French Government resumed its goal of standardizing aviation practices by hosting the Paris Peace Conference [12]. The Aeronautical Commission was formed, and the International Air Convention (ICAN) was subsequently

ratified by 38 member states, including the United States [12]. Years later, a Medical Subcommission was created to help delineate medical requirements and fitness for duty of pilots in the aviation career field. However, due to strained world relations and lack of commitment to the League of Nations, the ICAN began to lose momentum in this quest for standardized aviation practices [12].

The ICAN eventually closed with the onset of World War II, despite another explosion in aviation technology and capabilities resulting from the war [12]. Civilian aviation safety regulations were desperately needed; therefore, President Franklin D. Roosevelt hosted the Convention on International Civil Aviation, coined the Chicago Convention, after studying issues in aviation that needed international agreement [12]. ICAO was formally established in April 1947, becoming a specialized agency of the United Nations a year later [12].

Today, ICAO works in conjunction with other agencies worldwide to ensure safety in the aviation and navigation environments for the 189 Contracted States [3]. ICAO has promoted safe international civil aviation globally by establishing Standard and Recommended Practices outlined in 18 annexes that are mandatory for the member states to follow for the best interests of all civil aviation [12]. Each member state accordingly has its own governing body dedicated to implementing the requirements set forth by ICAO, such as the FAA in the United States and the European Aviation Safety Agency and Joint Aviation Authorities in Europe [2,12].

The World Health Organization (WHO) developed as a sister agency within the United Nations that established international standards for health [12]. Although there is no aerospace medicine subsidiary designated to the WHO, standards for prevention of disease transmission through transportation are a function of the WHO, implemented via the Guide to Hygiene and Sanitation in Aviation publication [12]. Additionally, WHO publishes several documents alerting travelers to international travel and health conditions [12].

The International Air Transport Association (IATA) was established in 1945 to promote world airline safety and economy [12]. Today, this organization represents over 240 airlines from 130 countries [12]. The Medical Advisory Group of IATA serves as a conduit between the business aspect of the commercial air transport industry and health issues, such as aircraft disinfection and control of communicable disease [12].

The onboard medical supply contents recommended by the Aerospace Medical Association in collaboration with the American Medical Association, with coordination through IATA, the International Academy of Aviation and Space Medicine, the American Osteopathic Association, the American College of Emergency Physicians, and ICAO [14], are presented in the Appendix. Of note, the use of AEDs is recommended based on risk assessment of the operator. Additionally, not every country is allowed to carry medication onboard; therefore, typical over-the-counter medications are recommended in these instances. Furthermore, universal precaution kits are strongly recommended by these governing bodies, given the nature of international travel [14].

Given the numerous countries that are members of ICAO, these lists of contents are general recommendations and not mandated items to be carried onboard airline transport aircraft, as different countries may have specific rules governing what is allowed to be carried onboard [14].

12.0 CONCLUSION

The medical resources onboard most civilian commercial airlines, the contents of the medical kits, and the training background of the crew in response to in-flight medical events were reviewed. Ground-based medical support agencies were introduced, and the physiology of the respiratory system was outlined. General guidance for responding to medical events onboard, with decision strategy for determining aircraft diversion, was provided, along with a discussion of the top four most common in-flight medical events. Finally, a brief history of international standards was also given to provide a comparison between the United States' procedures and those of the international communities.

As the overall health of our world's population improves, life expectancy will increase, leading to an older population using air transport. With this aged population comes a variety of chronic medical conditions that may become exacerbated during commercial flight, increasing the probability of in-flight medical emergencies. Thus, primary care providers need a better understanding of the aviation environment to make reasonable decisions concerning medical clearance for flying and knowledge of onboard capabilities and available resources to assist with providing care to the sick passenger in flight.

13.0 RECOMMENDATIONS

The medical community as a whole may benefit from a greater understanding of the aviation environment and how this can adversely impact a patient's chronic illness state. Also, since many healthcare providers are at some point passengers onboard commercial air transport aircraft, a greater understanding of managing in-flight emergencies, capabilities, logistics, and resources would also be beneficial for appropriate response procedures. Also, standardization of medical kits between the FAA and ICAO and maximum availability of AEDs during flight would likely improve the overall potential for successful assistance during an in-flight medical emergency.

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APPENDIX

Recommended Contents of Onboard Medical Supply Kits [21]

First Aid Kit

- Antiseptic swabs (10/pack)
- Bandage adhesive strips
- Bandage, gauze 7.5 cm x 4.5 cm
- Bandage, triangular 100 cm folded and safety pins
- Dressing, burn 10 cm x 10 cm
- Dressing, compress, sterile 7.5 cm x 12 cm approximately
- Dressing, gauze, sterile 10.4 cm x 10.4 cm approximately
- Adhesive tape, 2.5 cm standard roll
- Skin closure strips
- Hand cleanser or cleaning towelettes
- Pad with shield or tape for eye
- Scissors, 10 cm (if permitted by applicable regulations)
- Adhesive tape, surgical 1.2 cm x 4.6 m
- Tweezers, splinter
- Disposable gloves (several pairs)
- Thermometer (non-mercury)
- Resuscitation mask with one-way valve
- First aid manual (an operator may decide to have one manual per aircraft in an easily accessible location)
- Incident record form

Emergency Medical Kit

- Sphygmomanometer (electronic preferred)
- Stethoscope
- Airways, oropharyngeal (appropriate range of sizes)
- Syringes (appropriate range of sizes)
- Needles (appropriate range of sizes)
- IV catheters (appropriate range of sizes)
- System for delivering IV fluids
- Antiseptic wipes
- Venous tourniquet
- Sharp disposal box
- Gloves (disposable)
- Urinary catheter with sterile lubricating gel
- Sponge gauze
- Tape adhesive
- Surgical mask
- Emergency tracheal catheter (or large gauge IV cannula)
- Umbilical cord clamp

- Thermometer (non-mercury)
- Torch (flashlight) and batteries (operator may choose to have one per aircraft in an easily accessible location)
- Bag-valve mask
- Basic life support cards

Drug Kit

- Epinephrine 1:1000
- Epinephrine 1:10000 (can be a dilution of epinephrine 1:1000)
- Antihistamine injectable
- Anti-psychotic drug (e.g., haloperidol)
- Dextrose, 50% injectable, 50 mL (single dose ampule or equivalent)
- Nitroglycerin tablets or spray
- Major analgesic injectable or oral
- Sedative anticonvulsant injectable
- Antiemetic injectable or oral dissolvable (e.g., ondansetron)
- Bronchial dilator inhaler with disposable collapsible spacer
- Atropine injectable
- Adrenocortical steroid injectable or similar oral absorption equivalent
- Diuretic injectable
- Sodium chloride 0.9% (1000 mL recommended)
- Acetyl salicylic acid (aspirin) for oral use
- Oral beta blocker

Over-the-Counter Medications

- Mild to moderate analgesic for children and adults
- Antiemetic
- Nasal decongestant
- Antacid
- Antihistamine
- Antidiarrheal

Universal Precaution Kit

- Dry powder to absorb liquid
- Germicidal disinfectant
- Skin wipes
- Face mask and eye mask
- Disposable gloves
- Impermeable gown
- Large absorbent towel
- Pick-up scoop and scraper
- Biohazard disposal waste bag
- Instructions

LIST OF ABBREVIATIONS AND ACRONYMS

AED	automated external defibrillator
BLS	basic life support
CO_2	carbon dioxide
COPD	chronic obstructive pulmonary disease
CPR	cardiopulmonary resuscitation
FAA	Federal Aviation Administration
IATA	International Air Transport Association
ICAN	International Air Convention
ICAO	International Civil Aviation Organization
IV	intravenous
WHO	World Health Organization